Modeling, Data Assimilation and Reanalysis in Support of SPURS Cruise Planning and Data Synthesis

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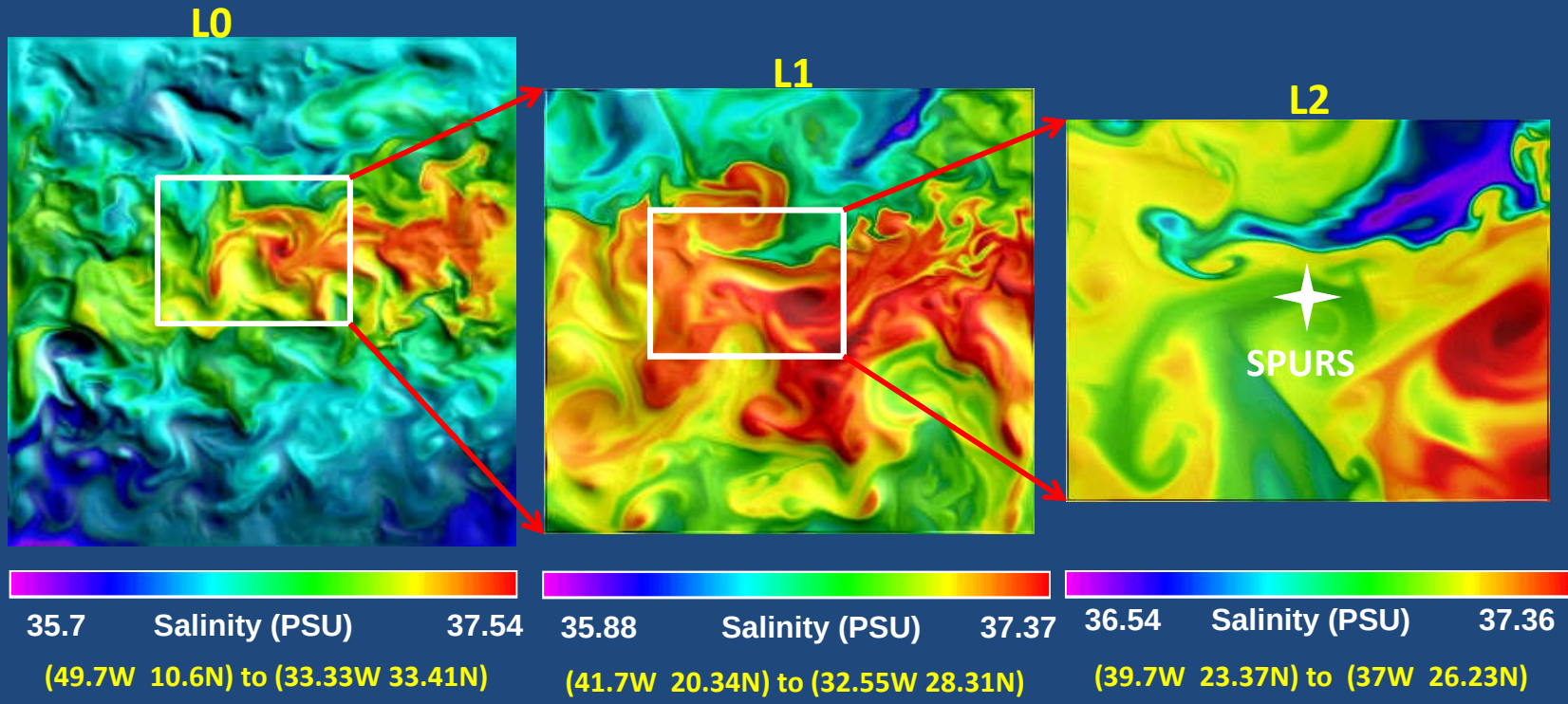
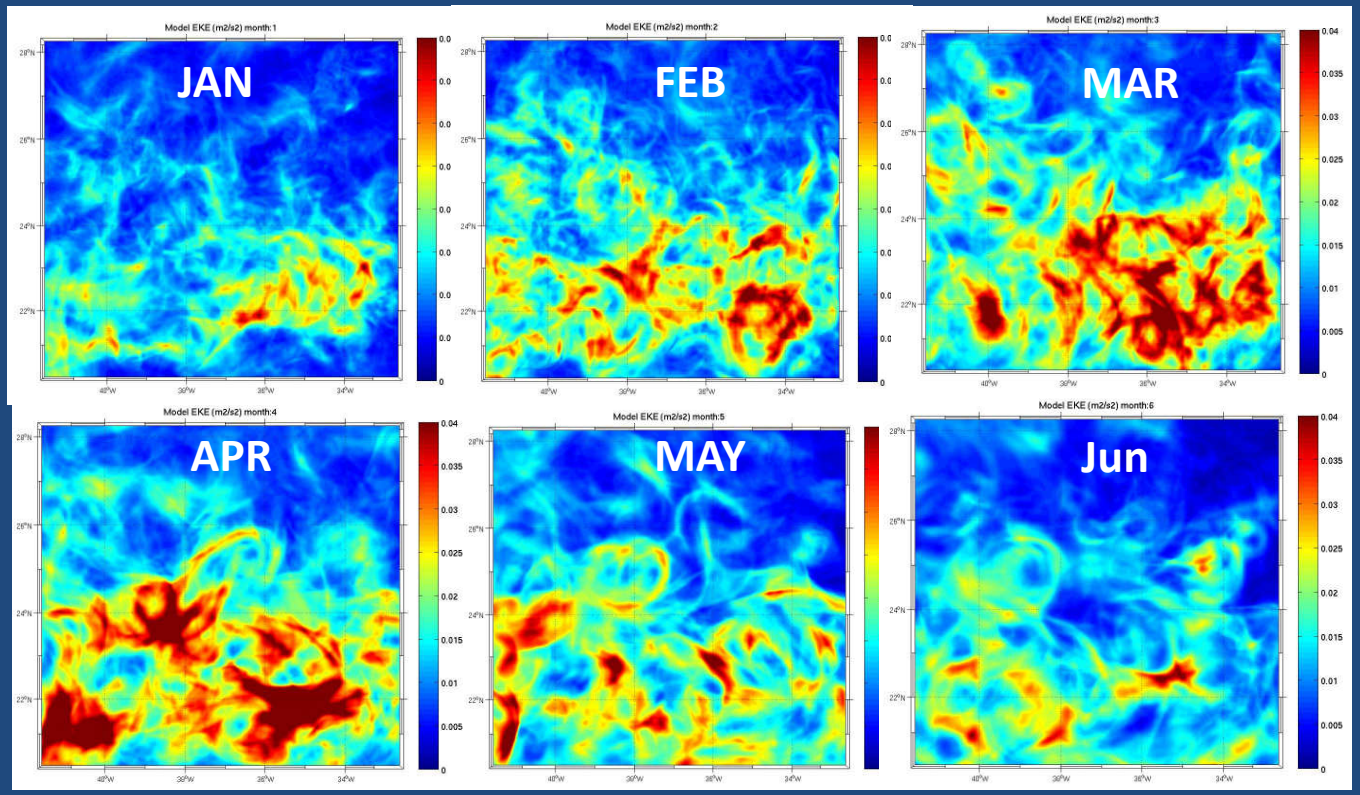
Three-Domain ROMS Model in Support of SPURS

- Three domain nested Regional Ocean Modeling System (ROMS) model
- A horizontal resolution of 9 km (L0), 3 km (L1) and 1 km (L2), with 50 vertical levels
- Three-hourly atmospheric forcing derived from the NCEP Global Forecasting System (NFS) products



Seasonal Cycle of Eddy Kinetic Energy

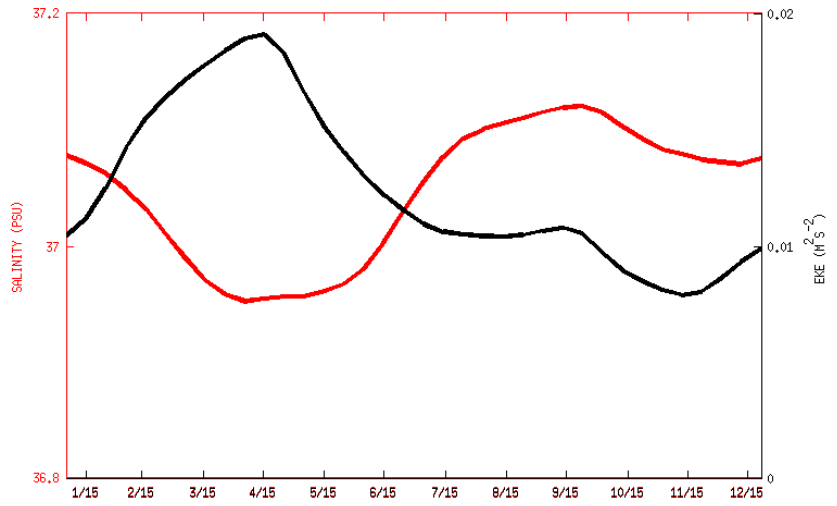


$$EKE = \frac{1}{2}(u'^2 + v'^2), u' = u - \bar{u}, v' = v - \bar{v}$$

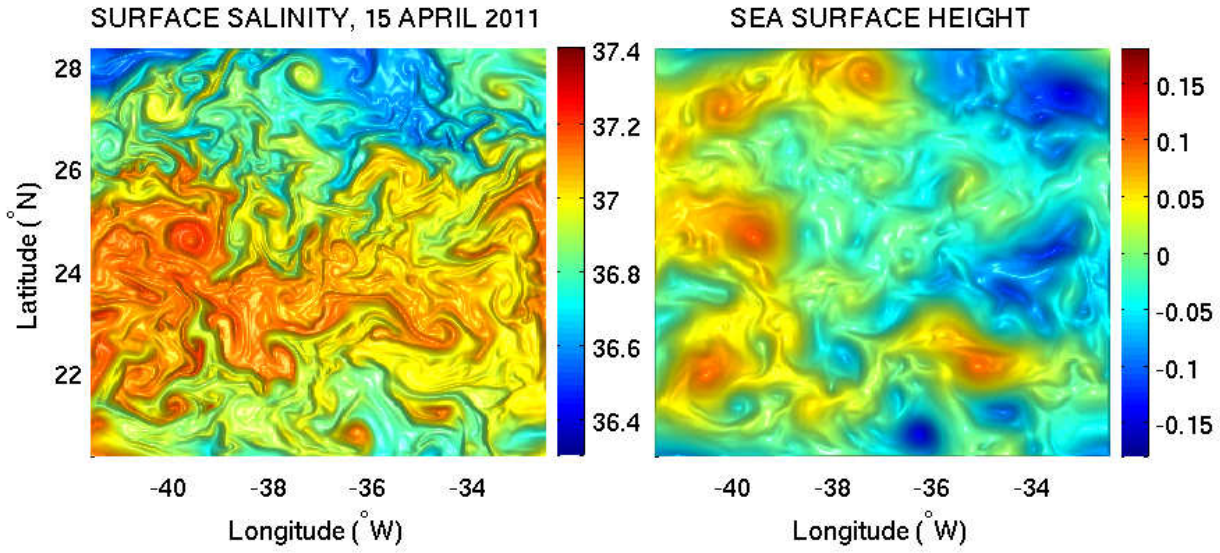
- Strongest eddy kinetic energy in Mar and Apr
- Weakest EKE in Sep and Oct

Simulations 2008-2011, 3-hourly atmospheric forcing from NCEP GFS

Eddy Kinetic Eddy and Sea Surface Salinity Seasonal Cycle



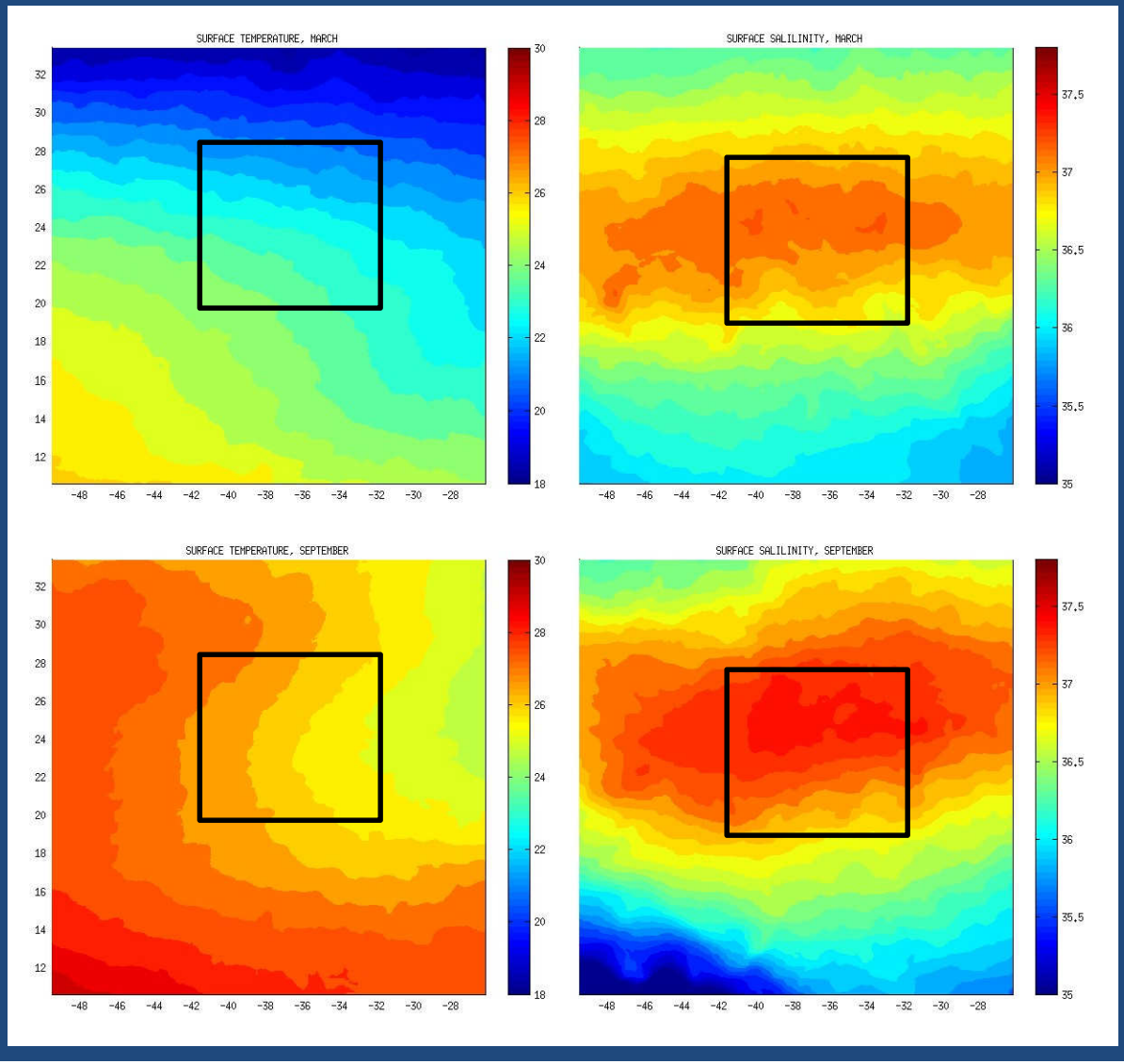
- EKE negatively correlated with SSS
- Complex relations for individual eddies



Seasonal Cycle of Gradients in SSTs and SSSs

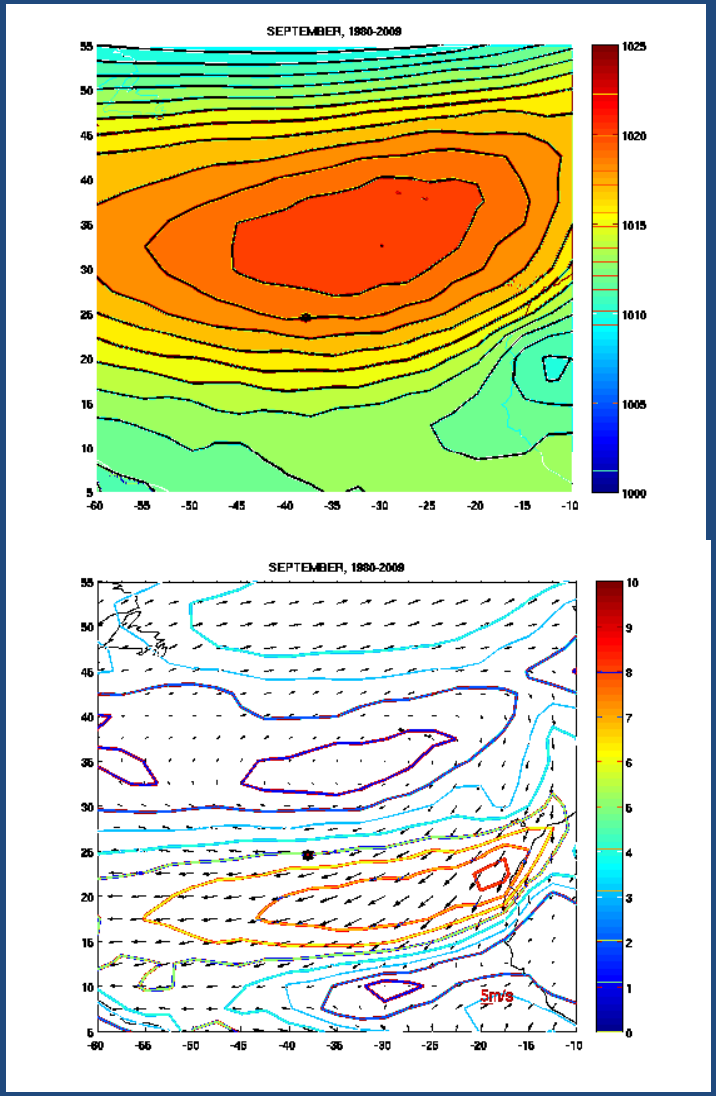
MAR

SEP

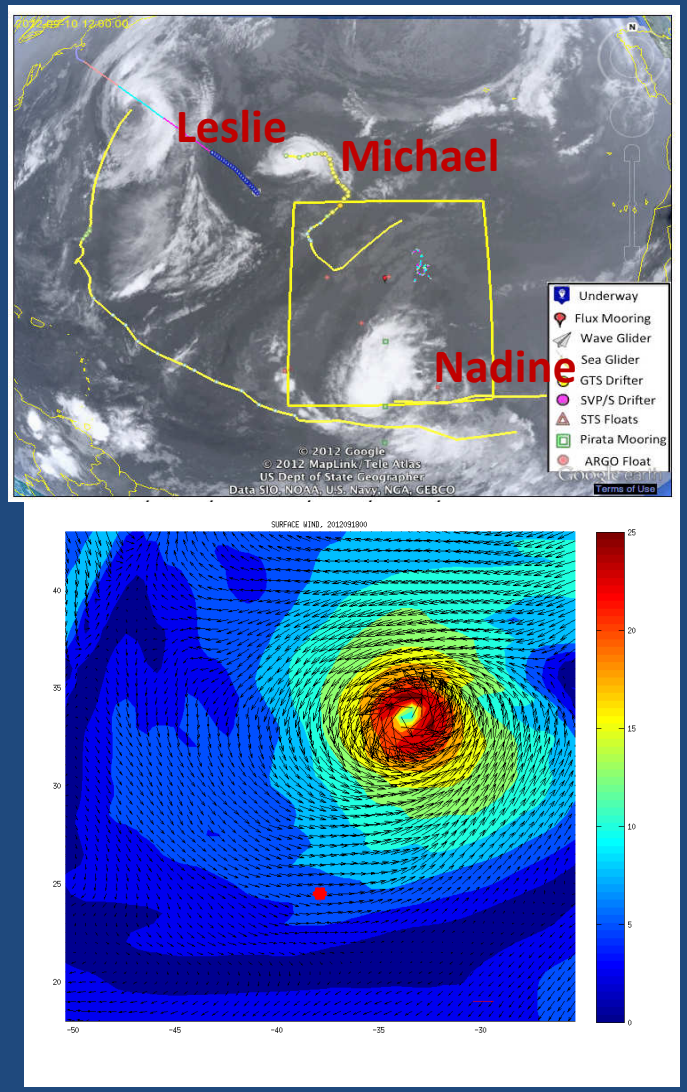


- Coupled gradients of temperature and salinity may create baroclinic and barotropic instabilities?
- Eddy activities are caused by the instabilities?

Extremely Abnormal Atmospheric Circulation during SPURS

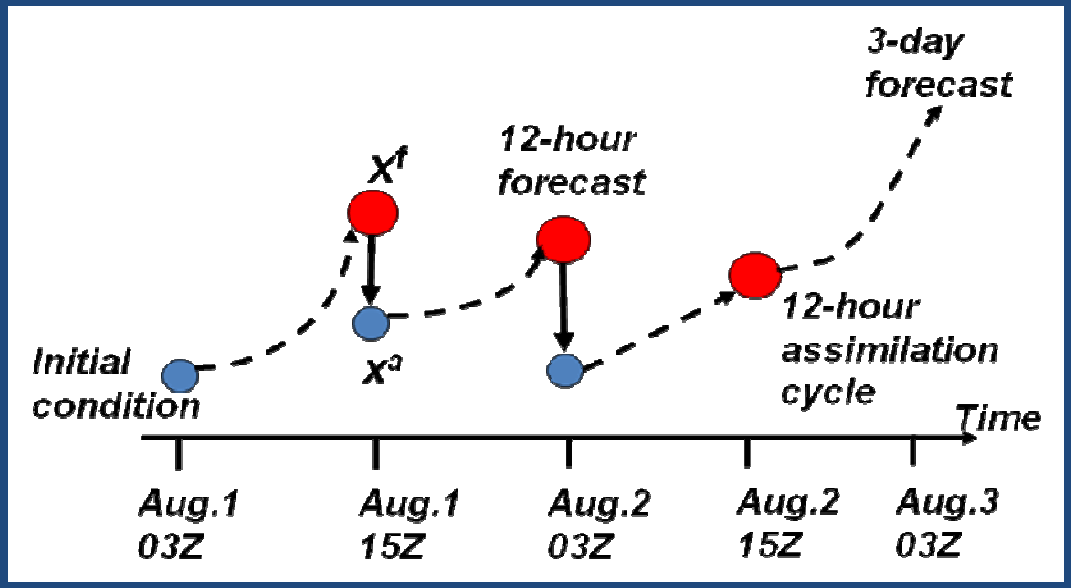


Climatology, September



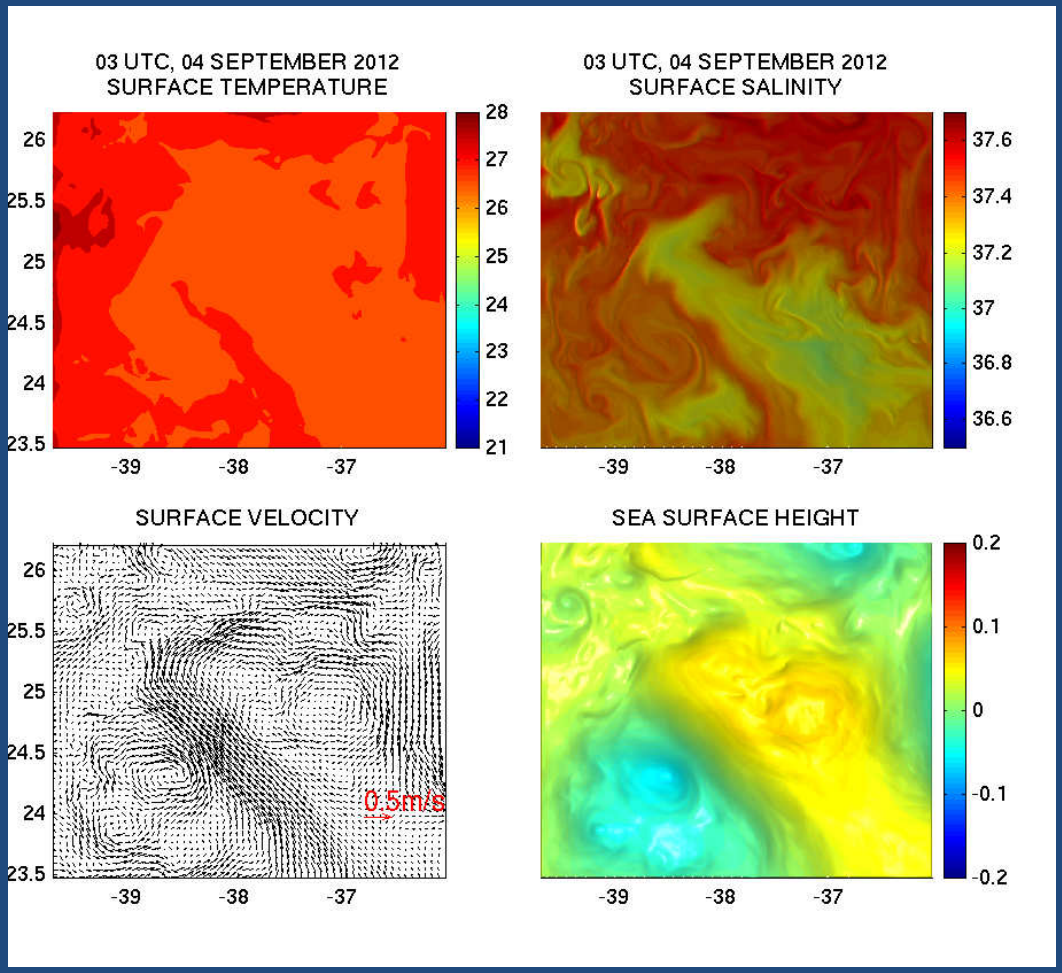
Nadine, September 18

Real-time Data Assimilation and Forecasting System Prior to SPURS



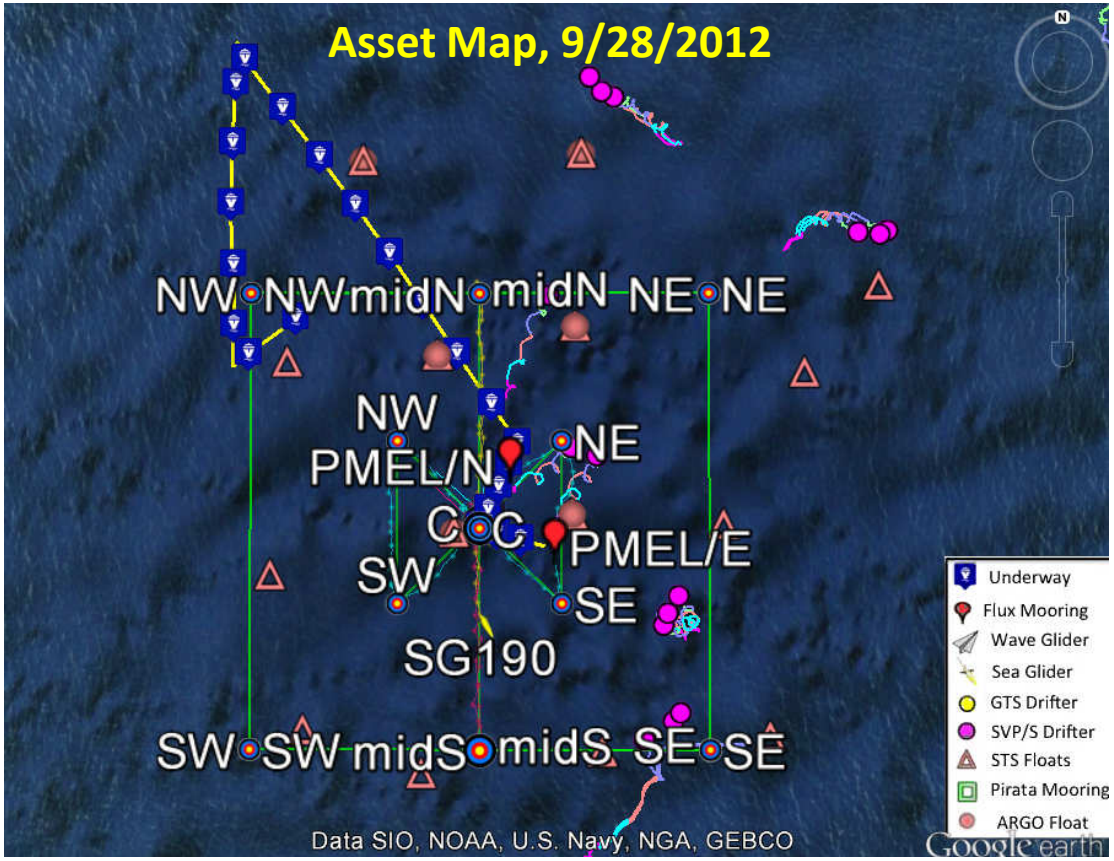
- The DA and forecasting cycle starts from July 15, 2012
- Observations assimilated includes
  1. Satellite SSTs (TMI, MODIS, AVHRR, ATSR, and GOES)
  2. Satellite SSHs
  3. Argo and mooring profiles, mooring profiles,
  4. ship SSTs

Skillful Model Forecast on Sep 4: Warmer SSTs, Higher SSSs, and Energetic Eddies



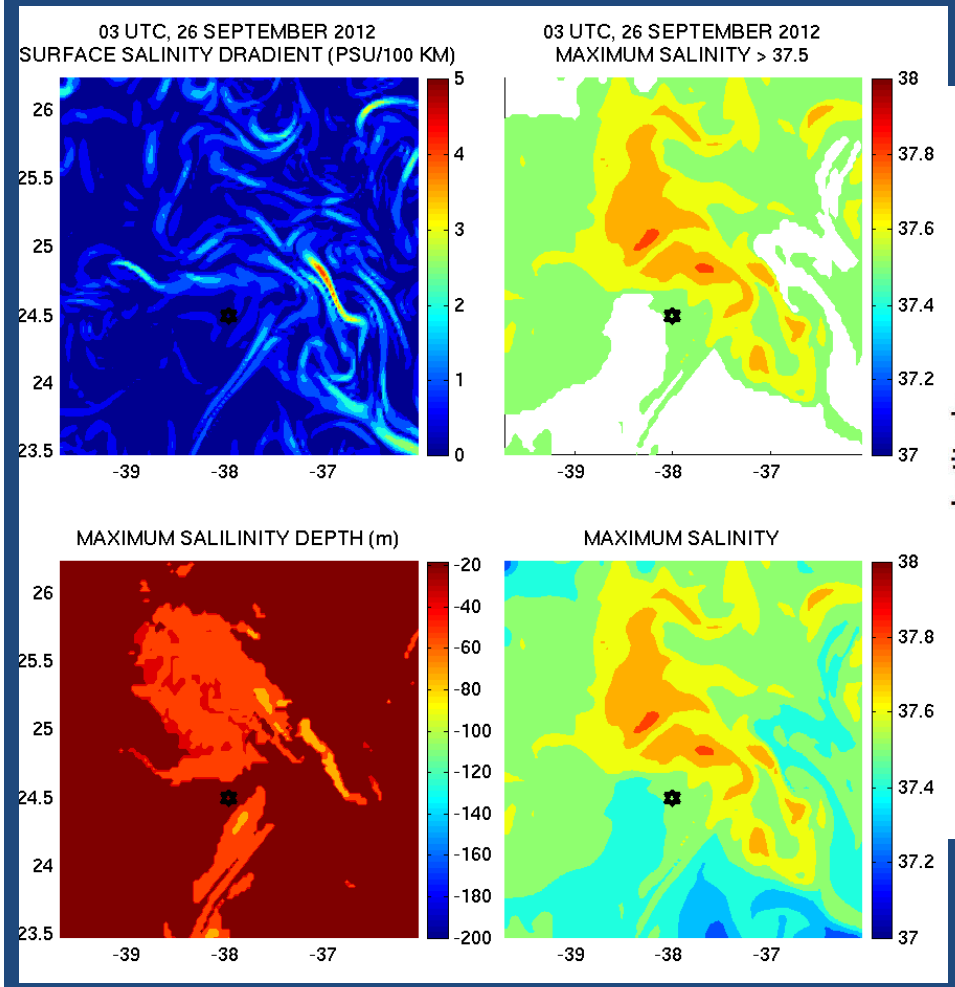
- Salinities of above 37.5 psu over extensive areas.
- In some areas, salinities are as high as 37.8 psu.
- Warmer SSTs and higher salinities within the SPURS area
- Significant eddy activities

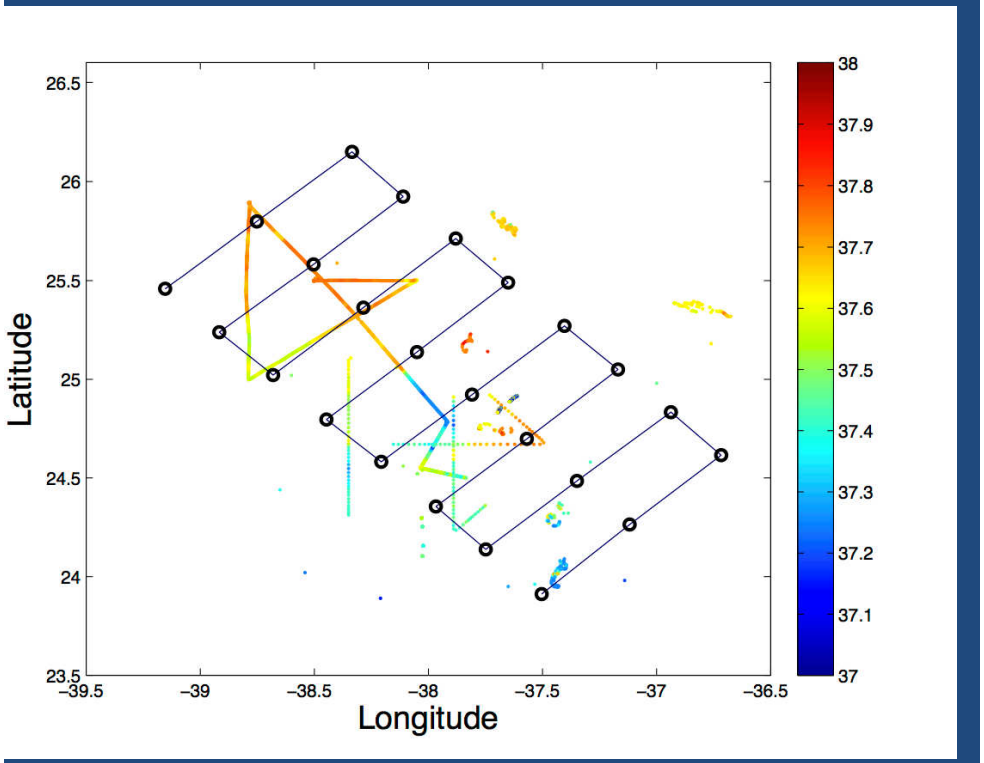
Assimilation of SPURS Observations



- T/S from the assets in the list are assimilated
- An observation minus forecast (O-F) check is applied for QC (0.35 psu and 4.0 C)

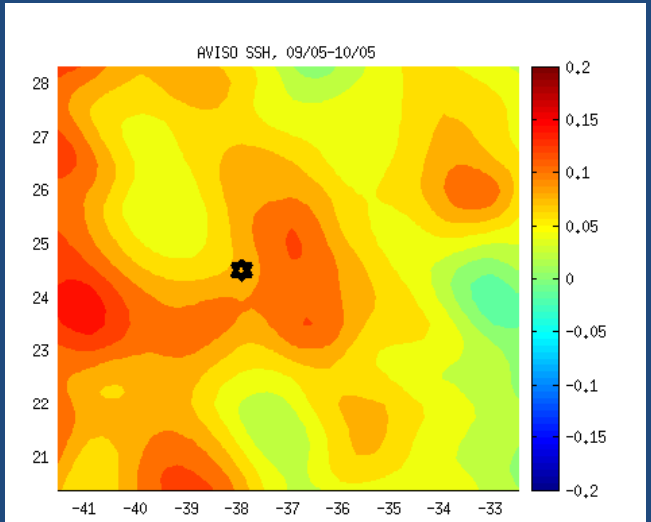
Prediction of Salinity Features

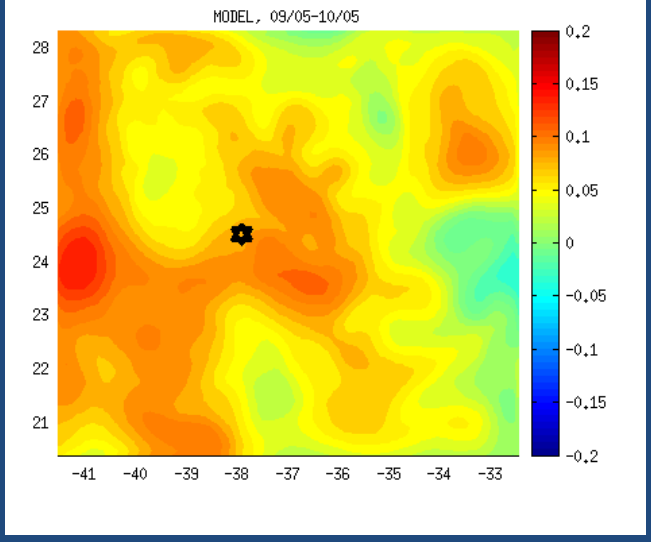


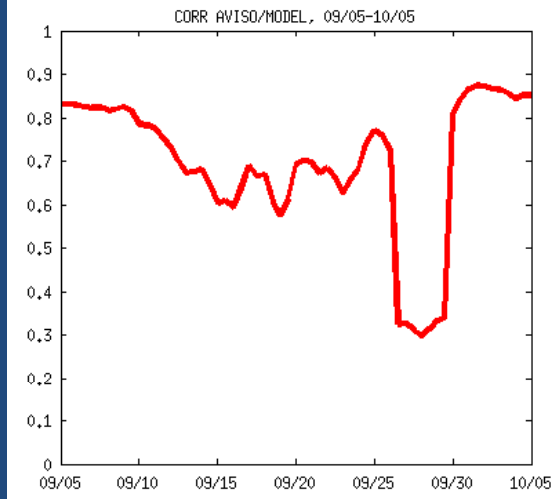


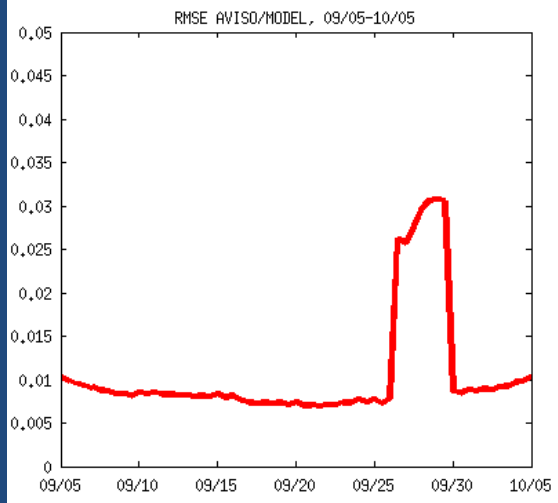
CTD survey

AVISO vs Model SSHs

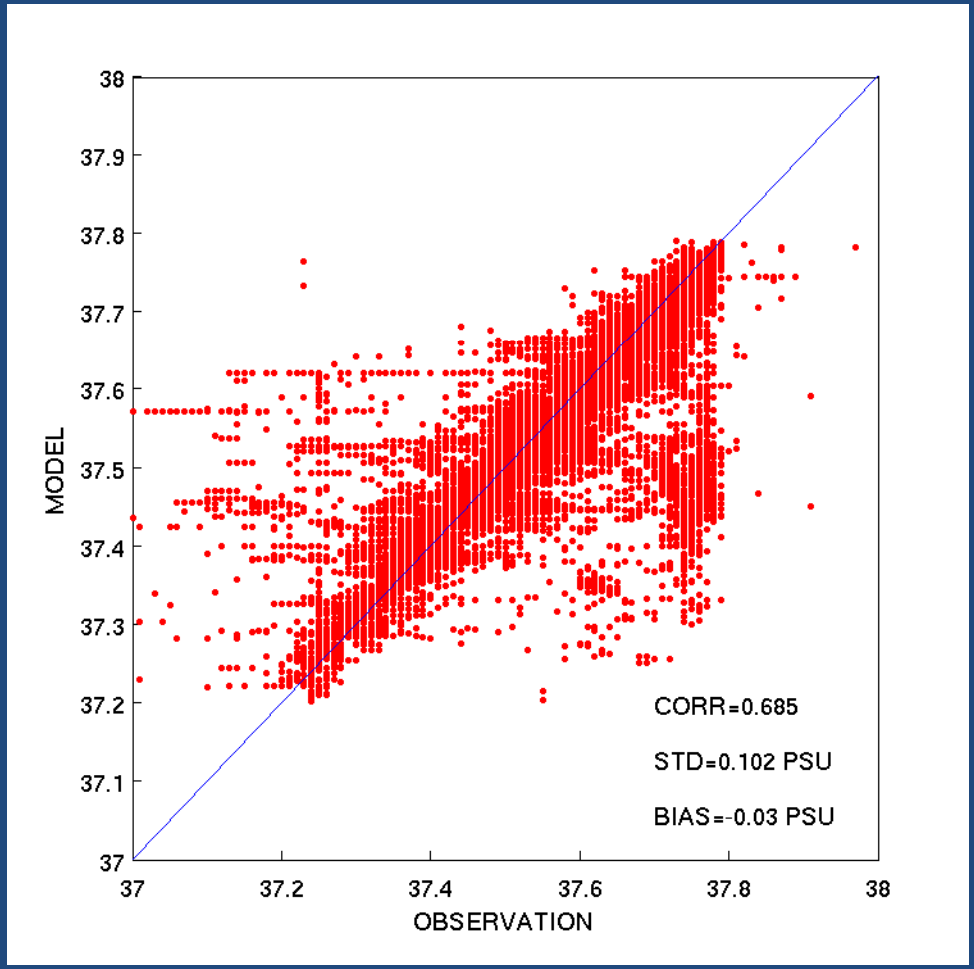








Evaluation of Model SSSs



Three-Dimensional Variational Data Assimilation (3DVAR)

$$x^a = x^f + K(Hx^f - y)$$

y observation

$$\min_x J(x) = \frac{1}{2}(x - x^f)^T B^{-1}(x - x^f) + \frac{1}{2}(Hx - y)^T R^{-1}(Hx - y)$$

$$\min_x J(\delta x) = \frac{1}{2}\delta x^T B^{-1}\delta x + \frac{1}{2}(H\delta x - \delta y)^T R^{-1}(H\delta x - \delta y)$$

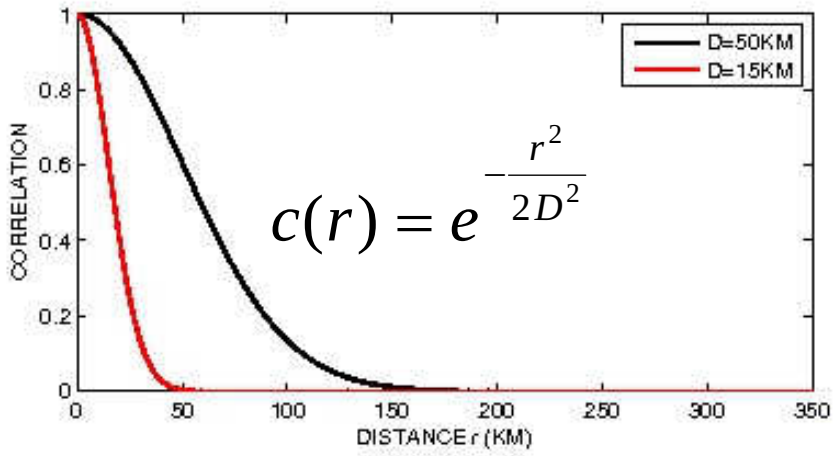
Fit to Background + Fit to Observation

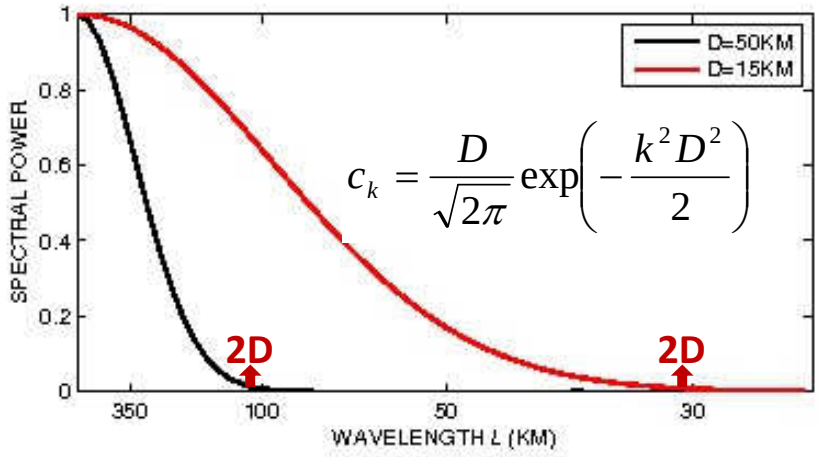
$$\delta y = y - Hx^f$$

Two requirements

1. **Dynamic balance**
2. **Decorrelation length scale**

Multi-Scale 3DVAR with Background Error Covariance of Multi-Decorrelation Length Scales





$$x = x_L + x_S$$

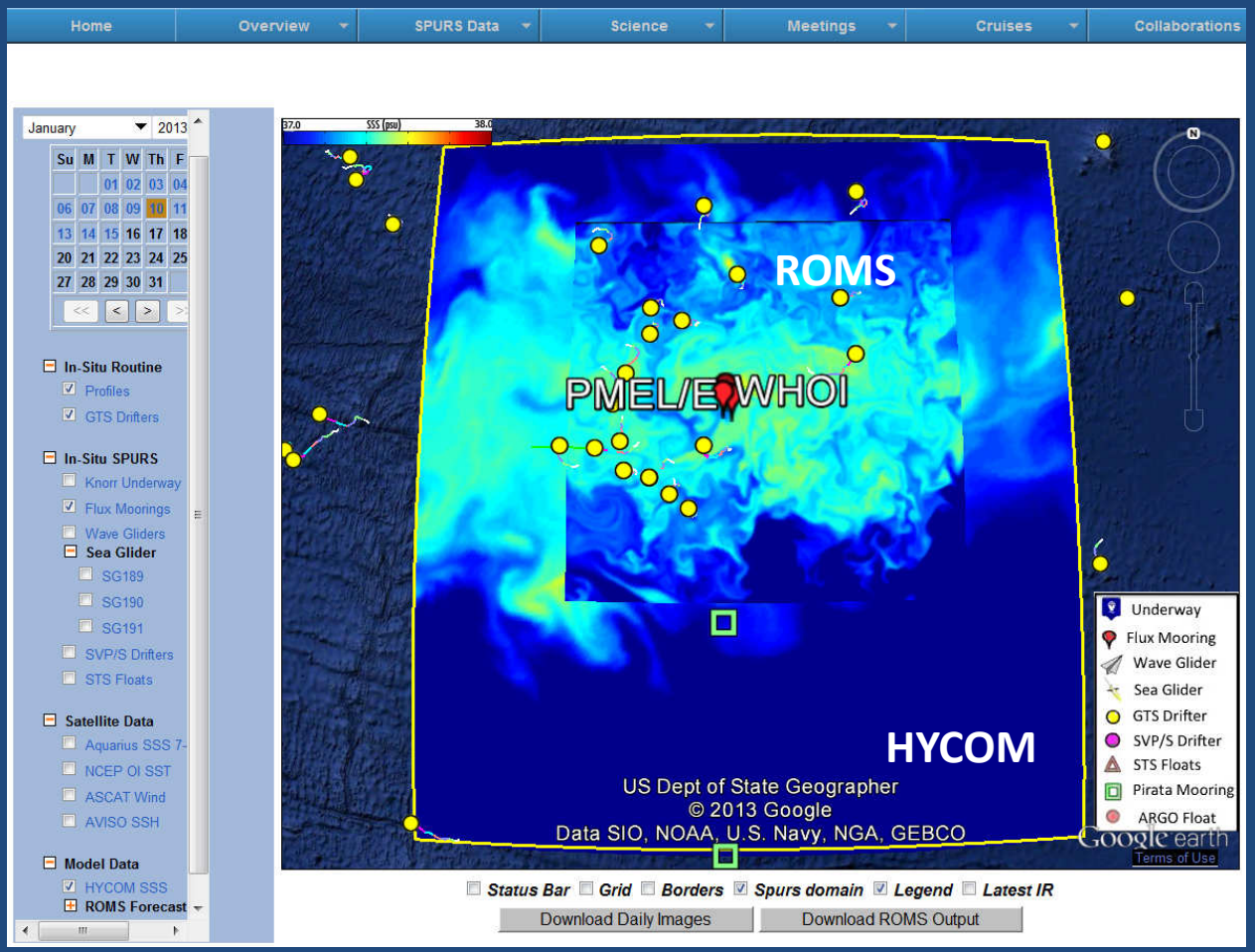
$$B = B_L + B_S$$

$$\min_x J(\delta x) = \frac{1}{2}\delta x^T \left(B_L + B_S\right)^{-1} \delta x + \frac{1}{2}(H\delta x - \delta y)^T R^{-1}(H\delta x - \delta y)$$

$$\min_{\delta x_L} J(\delta x_L) = \frac{1}{2}\delta x_L{}^T B_L^{-1} \delta x_L + \frac{1}{2}(H\delta x_L - \delta y)^T \left(HB_S H^T + R\right)^{-1}(H\delta x_L - \delta y)$$

$$\min_{\delta x_S} J(\delta x_S) = \frac{1}{2}\delta x_S{}^T B_S^{-1} \delta x_S + \frac{1}{2}(H\delta x_S - \delta y)^T \left(HB_L H^T + R\right)^{-1}(H\delta x_S - \delta y)$$

The Data Assimilation and Forecasting System for SPURS 2013



- Better Spinning up
- Bias correlated
- More effectively assimilating SPURS observations
- Forecasting more features
- …

Summary

- The SPURS data assimilation and forecasting system show encouraging capability of representing and predicting surface salinities
- Forecasting skill in meso-scale eddies and possibly submeso-scale eddies are demonstrated
- The SPURS system continue to work reliably and stably
- The multi-scale data assimilation system show the capability of integrating low-resolution satellite data and sparse profiles with highly dense SPURS observations
- Assimilation of Aquarius SSSs has been explored